Ir/Os CONSTRAINTS ON TERRESTRIAL ACCRETION AND CORE FORMATION.

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Summary. We report the first precise determinations of Ir/Os ratios in mantle peridotites by isotope dilution negative thermal ion mass spectrometry (ID-NTIMS). Abyssal peridotites from two separate dredges show control of Ir and Os abundances by nugget effects, in one instance (RC 27-9:6) yielding a precise Ir/Os=1.00±5, while the other dredge (RC 27-9:18) yields a variable Ir/Os=1.4±4, due to mineralogical control of Ir and Os by separate microphases, perhaps iridosmines. The presence of a chondritic Ir/Os value is consistent with heterogeneous accretion, but the nature of such a "late veneer" needs further refinement. High P/T core formation can account for the mantle Ir/Os only if $D^{metal\text{-}silicate}$ for Ir and Os are identical to 5%, which awaits substantial refinement of experimental techniques. Contributions from the core-mantle boundary (CMB) to plume sources should be resolvable as superchondritic Ir/Os, if nugget effects can be surmounted.

Highly siderophile elements such as Re, Os and Ir, are present in the Earth's upper mantle in chondritic relative proportions at Å2-3x10^{-3} CI concentrations. This may represent a signature of late accretion of chondritic material [1], high-P/T equilibrium during core formation [2], or interaction of outer core and mantle at the CMB [3]. Isotopic systematics for ^{187}Re-^{187}Os also require a precise definition of the upper mantle's siderophile element pattern. We approached these issues by the analysis of Re, Os and Ir by ID-NTIMS in mantle peridotite.

We analyzed abyssal peridotites since these are representative of MORB mantle. These peridotites differ from "primitive" mantle by the operation of at least three processes: mantle differentiation/melt removal, alteration and serpentinization, and submarine weathering. Since most mantle samples have suffered some loss (perhaps followed by gain) of melt, studies of primordial mantle PGE composition are restricted to those elements that are compatible (Ir, Os, Ru?). The abundances of Ir and Os in seawater are extremely low [4], so that weathering and hydrothermal alteration of peridotite play an insignificant role in determining Ir/Os ratio. The ^{187}Os/^{188}Os of seawater is quite distinct from mantle values (Å1.0 vs. 0.125±5), providing a tracer of seawater addition/exchange. The Ir/Os ratio in modern abyssal peridotites is expected to reflect that of the bulk (upper?) mantle. Abundances of Os and Ir and ^{187}Os/^{188}Os isotopic compositions were determined on the same samples using Carius tube digestion and NiS fusions. Rhenium abundances were obtained from the Carius tube digestions. Abyssal peridotites from two separate dredges of the Atlantis II Fracture Zone, Indian Ocean, were analyzed. Samples from dredge RC 27-9:6 yielded Ir/Os= 1.00±5, within error of chondritic values [5, 6], while those from dredge RC 27-9:18 yielded Ir/Os= 1.4±0.4. Variable Ir/Os ratios on replicate digestions of the same abyssal peridotite from RC 27-9:18 indicated the presence of nugget effects controlled by a phase with Ir/OsÅ 2 (e.g. iridosmine). These peridotites yielded ^{187}Os/^{188}Os= 0.128, with ^{187}Re/^{188}Os= 0.18-0.32, depleted relative to chondrite values of ^{187}Re/^{188}Os=0.396 [6] by melt removal. We regard the ^{187}Os/^{188}Os values to be upper limits, until further experiments can establish the influence of submarine alteration. Arc xenoliths from Ichinomegata and Simcoe yielded Ir/Os=1.4±0.2, perhaps indicative of PGE mobility recognized using ^{187}Os/^{188}Os [7].

A "best" value of the mantle Ir/Os= 1.00±0.05 is obtained from RC 27-9:6 peridotites. This value is similar to those of ordinary (Ir/Os=0.93±0.05) and carbonaceous chondrites (Ir/Os= 0.95± 0.04). Enstatite chondrites have a broad range of Ir/Os values (0.87±0.10). Better Ir/Os values for chondrite classes and mantle peridotites must be obtained before accretionary signatures of specific chondrites can be recognized in the terrestrial mantle. Signatures based on Ir/Os may prove to be more robust than those based on elements that fractionate during melting.

New metal-silicate partition coefficients for Re indicate that homogeneous accretion might account for the mantle's Re abundance by formation of the core at appropriate P, T and compositional values [2]. The existence of chondritic Ir/Os and Re/Os [8] in the mantle is a challenge for "homogeneous accretion" followed by core formation models since it imposes the condition that the partition coefficients for these elements must be virtually identical. Given that these are controlled by P, T, f_{O_2}, f_{S_2} and other compositional parameters, this must be a very restrictive condition. Our knowledge of $D^{metal\text{-}silicate}$ for high-P/T fractionation of Re, Os and Ir need to be refined so that these are comparable to the mantle database in precision.

We have also provided a "normal" mantle baseline against which contributions of Ir and Os from the outer core to plume sources at the CMB can be detected if the outer core has an Ir/Os ratio distinct from chondrites. Iron meteorites undergoing crystal-liquid fractionation in asteroidal cores (IIAB, IIIAB) exhibit Ir/Os upto 4 [9], leading to the expectation that any outer core contribution to plume sources will result in higher Ir/Os, which should be resolvable, after elimination of nugget effects. Sampling strategies to overcome nugget effects are important to better utilize the isotope dilution technique for Ir/Os ratios.

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Figure: ID-NTIMS Ir/Os ratios in terrestrial samples (filled symbols) compared with literature RNAA data (open symbols). Chondrite values shown as gray shaded region. KAL-1 is a komatiite from Alexo, Ontario; literature Alexo komatiite data [10]; abyssal peridotites; arc xenoliths from Ichinomegata and Simcoe; subcontinental mantle xenoliths [8]; mean values of C3 chondrites [11, 12], H,L,LL [11] and E [13, 14].